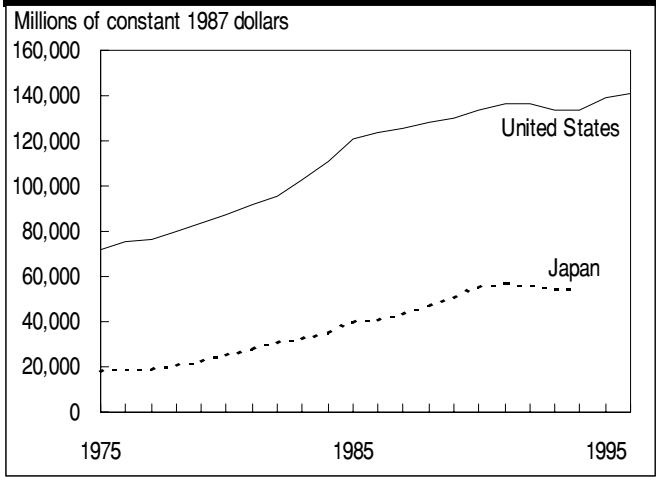
CHAPTER 1. NATIONAL R&D PATTERNS

TOTAL R&D EXPENDITURES

In the last two decades, both the United States and Japan have had strong growth in R&D, followed by slight annual declines from 1991–94. The similarity in this pattern of growth can be seen in figure 1. Japan's national expenditures on R&D grew at an average inflation-adjusted annual rate of more than 7 percent between 1975 and 1991, from $18 billion in 1975 to a peak spending of $57 billion in 1991.[8] During this period, U.S. real growth in R&D investments was strongest between 1975 and 1985 (5 percent annually). In the later half of the 1980s, growth in overall R&D in the United States shifted to a more modest rate of increase (2 percent annually), reaching $136 billion in 1991.

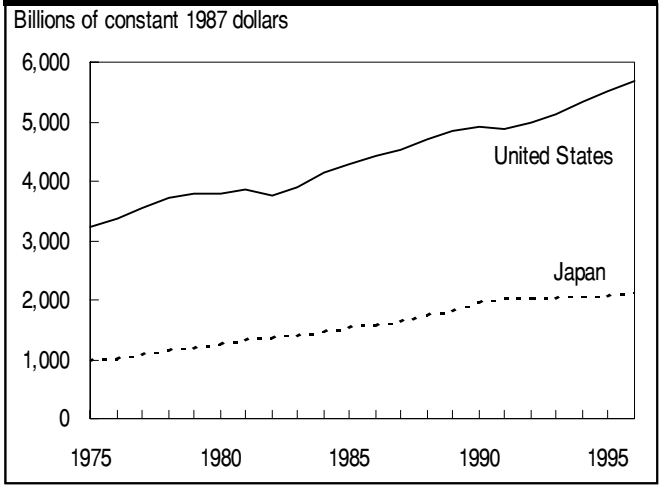
Figure 1. Total R&D expenditures



See appendix table A-1.

U.S. national R&D declined during 1993–94 in constant dollars, in part due to a decline in military R&D spending and in part from a slowdown in industrial R&D funding. In Japan, overall R&D declined in 1993 and 1994, not from cuts in military spending, but from the decrease in industrial R&D caused by Japan's economic recession. Figure 2 shows the accelerated growth in Japan's GDP (5 percent annually) from 1975–91, followed by a stagnant GDP from 1991–94. The sharp appreciation of the yen accelerated offshore production and concerns about "hollowing out" of Japanese industry and rising unemployment. These economic problems provided the political urgency for dramatic changes in Japanese S&T policy in 1995, to stimulate the economy in the short run and revitalize the economy in the long run.

Figure 2. Total GDP



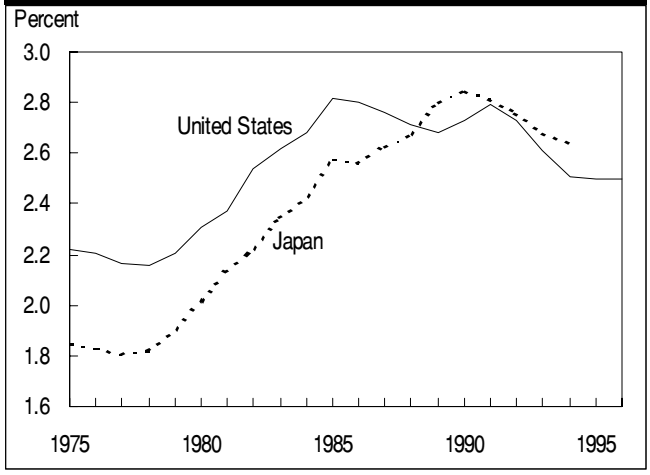
See appendix table A-2.

Even with recent industrial cutbacks in R&D, for the relative size of its economy, Japan invests an amount in R&D slightly larger than that of the United States. With a gross domestic product (GDP) that was approximately 39 percent of that of the United States ($2.1 billion versus $5.3 billion) in 1994 (figure 2), Japan's overall R&D expenditures were 41 percent of those of the United States ($54 billion versus $133 billion) (table A-1). Thus, Japan invests a slightly higher percentage of its GDP in R&D (2.6 percent versus 2.5 percent, respectively) (figure 3).

In non-defense R&D, Japan significantly outspends the United States relative to its GDP. Defense R&D in the United States declined to 20 percent of overall R&D by 1994, from a high of 32 percent in 1987. In contrast, Japanese defense research is only 1 percent of overall R&D. Japan has invested between 2.5 percent and 2.8 percent of its GDP in civilian

[8] Budget figures provided in this report are adjusted for inflation (constant 1987 dollars). The deflators for the Japanese yen are provided in appendix table 1, as well as the purchasing power parity conversions used for the dollar amounts. Japanese R&D data are taken from OECD's *Main Science and Technology Indicators*, and cover the period from 1975–94. This report uses the adjusted series for Japan. See methodology and technical notes on OECD Adjusted Data for Japan. Japan's government R&D budget authorizations for 1995–97 provide more recent evidence of the significant changes occurring in Japanese R&D.

Figure 3. Total R&D/GDP ratios

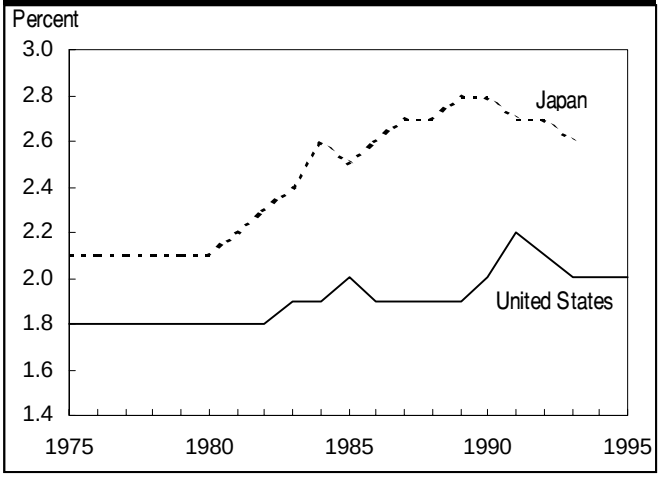


See appendix table A-2.

research for the past 10 years. (See figure 4.) The United States has invested approximately 2.0 percent of its GDP in civilian R&D over the period 1975–94.

Government investment in non-defense R&D as a percent of GDP shows an even wider gap between the United States and Japan. Estimated government nondefense R&D expenditures as a percent of GDP reached 0.51 percent in Japan in 1996. U.S. Government expenditures for nondefense research were 0.40 percent of GDP in 1995 (table A-3).

Figure 4. Nondefense R&D/GDP ratios

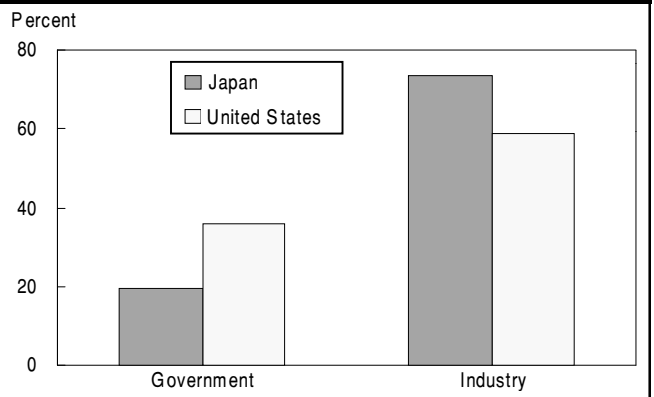


See appendix table A-3.

R&D Expenditures by Source and Performer

Industry historically has funded a larger share of R&D in Japan than has the government sector. However, the long-term trend in Japan of a continual decline of government as a source of R&D funding reversed itself in the 1990s. In the 1970s the Japanese government funded approximately 30 percent of total R&D. This government proportion declined at 5 percent annually throughout the 1980s, and represented only 16 percent of overall R&D by 1990. In that year, industrially funded research reached 78 percent of total R&D in Japan. Since 1992, however, government expenditures represent an increasing percentage of the total, while industry funding of R&D is declining as a percent of total R&D. By 1994, government support of total R&D reached almost 20 percent; industry declined to 73 percent (table A-4 and figure 5).

Figure 5. National R&D by source of funds: 1994

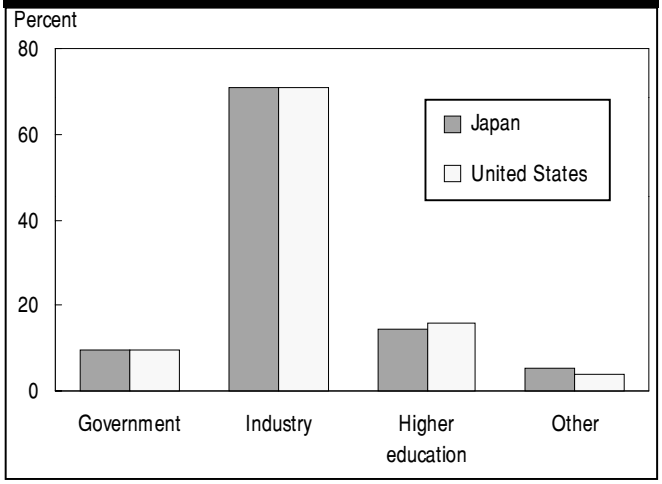


See appendix table A-4.

The government of the United States has been a more significant source of support for R&D than that of Japan if defense R&D is included. U.S. Government sponsored research grew rapidly in the 1980s, peaked in 1987, and has since declined, following the worldwide reductions in defense R&D since the late 1980s. U.S. Government support of overall R&D fell from 45.8 percent in 1985 to 35.0 percent in 1995 (table A-4).

In the performance of research, Japan and the United States have a similar pattern of shares of research performed by industry, higher education, and government (figure 6). Japanese industry increased its share to 76 percent of total research by 1990. In the past 5 years, however, industry research dropped to 72 percent of overall R&D, as universities and national laboratories have accounted for an increasing share of research performed in Japan. In the United States, the proportion of R&D performed by industry has increased from 68 percent in 1975 to a peak of 74 per-

Figure 6. National R&D expenditures by performer: 1994



See appendix table A-5.

increased from 68 percent in 1975 to a peak of 74 percent in 1985, with a slight decline since then. Coinciding with this industrial research was a decade-long trend in the United States toward a somewhat larger share of R&D performed by universities, from 11.6 percent in 1985 to 15.7 percent in 1994 (table A-5).

R&D by Character of Work

Based on OECD data, Japan and the United States report relatively similar proportions of basic, applied, and development work, with basic research having a slightly higher proportion of total R&D in the United States than in Japan. In 1992, 16.3 percent of R&D expenditures in the United States went to basic research. In that same year, 13.9 percent of R&D expenditures in Japan went to such research (table A-6). In the national survey of R&D, Japanese industry reports that they perform a significant amount of this basic research (about 37 percent).

Japan plans to increase its conduct of basic research and improve laboratory conditions in universities. The background to the Basic Law for Science and Technology states that the conditions for basic research in Japan are far below standards and conditions in the United States and Europe. The increase in the government funding of science is to improve these conditions, and to pursue frontier research in science and technology.

Scientists and Engineers

Japan has more engineers as a proportion of its overall labor force than the United States. In fact, relative to the size of its labor force, Japan has more engineers than any leading industrial nation except Sweden (NSF, 1996c). This engineering concentration stems from the large number of engineering degrees earned at the undergraduate level in Japan. (See section on Higher Education: undergraduate level.) In 1990, Japan had 342 scientists and engineers per 10,000 members of the non-academic labor force, compared with 281 for the United States in 1991. The engineering labor force in Japan is concentrated in fields of electrical and electronic engineering and computer processing technology (table 1). Based on the large number of engineering degree recipients entering the labor force each year, Japanese industries hire engineers in the services, manufacturing, and construction branches of their economy far more often than similar industries in the United States.

In contrast to large numbers of engineers, Japan still has relatively few employed scientists in their labor force. In 1991 the United States had 135 non-academic scientists per 10,000 members of the labor force compared with 104 in Japan in 1990, but the gap is narrowing (table 1).

The increasing concentration of science and engineering personnel in the Japanese labor force contrasts with the situation in the U.S. labor force. The stock of scientists and engineers relative to the labor force is sharply increasing in Japan; while only moderately increasing for scientists in the United States. The Japanese stock of scientists and engineers grew 8.0 percent annually from 1985–90 (table 1). During the same time period, the Japanese labor force grew at 1.4 percent annually. In contrast in the United States, the stock of engineers remained stable between 1986 and 1991, at 146 per 10,000 of the labor force. The U.S. stock of scientists relative to the labor force moderately increased from 109 per 10,000 of the labor force in 1986 to 135 per 10,000 in 1991, representing a 4-percent annual growth rate. The U.S. labor force grew 1.2 percent annually from 1986–91.

Table 1. Stock of scientists and engineers: various years /1

Category	Japan			United States		
	1980	1985	1990	1980	1986	1991
Scientists and engineers, total	940,301	1,514,200	2,224,347	2,369,200	3,047,000	3,560,000
Per 10,000 labor force 2/	166	252	342	218	255	281
Engineers	744,380	1,124,300	1,549,776	1,486,400	1,749,000	1,846,000
Per 10,000 labor force	132	187	238	137	146	146
Civil 3/	351,929	485,400	719,167	214,300	233,000	223,000
Electrical/electronic	119,499	233,100	318,277	351,600	550,000	562,000
Industrial and mechanical 4/	272,952	405,800	512,332	920,500	966,000	1,061,000
Scientists	195,921	389,900	674,571	882,800	1,298,000	1,714,000
Per 10,000 labor force	35	65	104	81	109	135
Natural	63,729	67,100	110,364	471,400	420,000	466,000
Computer	129,764	320,500	558,463	192,100	580,000	876,000
Social	2,428	2,300	5,744	219,400	298,000	372,000

1/ Non-academic scientists and engineers employed as scientists and engineers.

2/ Table A-7 shows labor force numbers used for each country, based on OECD data.

3/ Civil engineering includes surveying and architects.

4/ Industrial/mechanical engineering includes agriculture and forest technology, chemical, mechanical, metallurgical, mining, and other engineering and technology.

SOURCES: National Science Foundation, Division of Science Resources Studies, The *Science and Technology Resources of Japan: A Comparison with the United States* (Washington, D.C.: NSF 88-318); U.S. Bureau of the Census, Center for International Research, *Scientists and Engineers in Industrialized Societies* (Washington, D.C.: U.S. Bureau of the Census, 1992) and *Scientists and Engineers in* Japan: *1990* (Washington, D.C.: U.S. Bureau of the Census, 1996). See Technical Notes for differences in sample size used for tabulations in these publications.

The United States, however, has more women scientists and engineers in the labor force than does Japan. In the United States, women account for 38 percent of the non-academic scientists and 8 percent of the non-academic engineers. In Japan, women hold only 15 percent of the non-academic science positions and 3 percent of the engineering positions (table 2).

Distinct from the total stock of scientists and engineers is the number who are currently active in R&D. Two decades ago, the United States had more scientists and engineers engaged in R&D relative to its labor force than did Japan. These positions have reversed in the 1990s. Although the United States still has about twice the number of research scientists and engineers as does Japan, relative to the size of its labor force, Japan now has more research scientists and engineers than the United States. In 1993, Japan had 80 research scientists and engineers per 10,000 of the labor force. In that same year, U.S. researchers numbered 74 per 10,000 of the labor force. In Japan, a long-term trend of a 4-percent annual growth rate of active research scientists and engineers continued

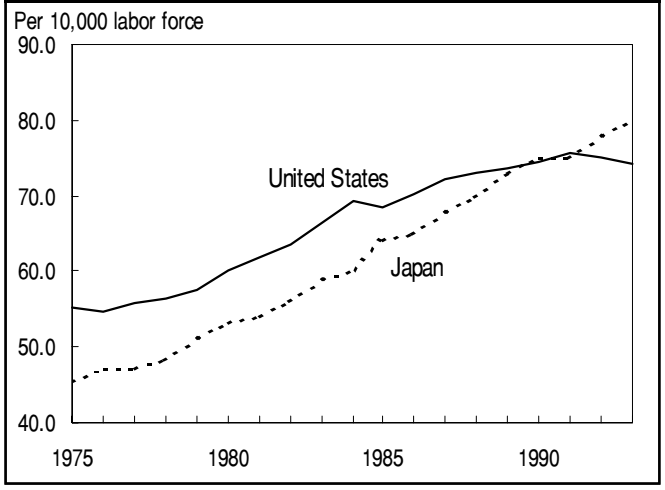
Table 2. Employed (non-academic) scientists and engineers, by sex

Category	Japan (1990)		United States (1991)	
	[Number]	[Percent]	[Number]	[Percent]
Scientists and engineers				
Total	2,224,347	100.0%	3,560,000	100.0%
Male	2,079,527	93.5	2,760,000	77.5
Female	144,820	6.5	800,000	22.5
Scientists	674,571	100.0	1,714,000	100.0
Male	570,724	84.6	1,066,000	62.2
Female	103,847	15.4	648,000	37.8
Engineers	1,549,776	100.0	1,862,000	100.0
Male	1,508,803	97.3	1,694,000	90.9
Female	40,973	2.7	152,000	8.1

SOURCES: U.S. Bureau of the Census, Center for International Research, *Scientists and Engineers in Industrialized Societies* (Washington, D.C.: U.S. Bureau of the Census, 1992) and *Scientists and Engineers in Japan: 1990* (Washington, D.C.: U.S. Bureau of the Census, 1996). See Technical Notes for differences in sample size used for tabulations in these publications.

throughout the period from 1975–93. The number of research scientists and engineers in the United States showed comparable growth from 1975–91, but has since grown more slowly. Growth in employment of research scientists and engineers in the United States was less than 1 percent (average annual increase) between 1990 and 1993 (table A-7 and figure 7).

Figure 7. Scientists and engineers in R&D



See appendix table A-7.

The Japanese have a higher percentage of their R&D scientists and engineers (RSEs) working in the higher education sector than does the United States, 21.8 percent versus 13.3 percent, respectively (table 3). As in the United States, relatively few of Japan's RSEs are employed in government laboratories. Under the new legislation, the Japanese government is focusing particularly on the scientists and engineers in universities and national laboratories—numbering approximately 145,000—to create for them an environment more conducive to breakthrough research (table 3). The government R&D section describes new competitive funding programs aimed at enhancing the capacity for basic research, mainly in the university sector.

The number of permanent government researchers will not increase as the government budget for science increases, so a very significant component of the new programs is the ability of faculty and directors of national laboratories to hire postdoctorate researchers and research assistants. In fact, the total number of government employees will likely decrease by some percentage each year as the Japanese government

Table 3. Number of scientists and engineers engaged in R&D by sector: 1993

Sector	Japan	United States	Japan	United States
	[Number]		[Percent]	
Total	526,501	962,700	100.0%	100.0%
Industry	367,278	764,500	69.7	79.4
Higher education	114,582	128,000	21.8	13.3
Government and private non-profit	29,907	60,000	5.7	6.2
Other	14,734	10,200	2.8	1.1

NOTE: Japanese data are based on OECD adjusted numbers for full time equivalents (FTE).

SOURCES: Organization for Economic Co-operation and Development,Technology Indicators, Paris, OECD, 1995; Government of Japan, National Institute of Science Main Science and and Technology Policy, Science and Technology Agency, *Science and Technology Indicators* : *1994* , NISTEP Report No. 37 (Tokyo, 1995); Science Resources Studies Division, National Science Foundation, *National Patterns of R&D Resources: 1996* (Arlington, VA: NSF, 1996).

decreases its hiring and the ceiling on S&E personnel in national laboratories (Ichikawa, 1996). Thus, new programs, which include funding for research assistants and postdoctorate positions, provide research directors the opportunity to expand their activity. While lifetime employees in universities will decrease, opportunities for fixed-term appointments (of various lengths of time) will increase. The Japanese government plans to fund about 10,000 graduate and postdoctoral positions a year.

Reforms for S&E personnel are also underway at the National Personnel Authority (NPA), which tightly controls hiring of research personnel for all national universities and national research institutes. There is currently a civil service entrance examination and a set of interviews that regulate the hiring of any professor or research scientist at national universities or institutes. Reforms are being discussed to deregulate personnel hiring in the academic sector over the next several years, so that national universities and institutes could hire scientists they want to have for their particular research strengths or teaching skills (Ichikawa, 1996).